PRELIMINARY INSTRUCTIONS

FOR

FREQUENCY METER SET SCR-211-AA

MANUFACTURED BY

PHILCO CORPORATION
PHILADELPHIA, PA., U. S. A.

RESTRICTED

NOTICE:—This document contains information affecting the national defense of the United States within the meaning of the Espionage Act (U. S. C. 50:31, 32 as amended). The transmission of this document or the revelation of its contents in any manner to any unauthorized person is prohibited.

The information contained in documents marked RESTRICTED will not be communicated to the public nor to the press, but it may be communicated to any person known to be in the service of the United States, and to persons of undoubted loyalty and discretion who are cooperating in governmental work. (AR380-5).

for Airplane Type B17-G
AAF Serial No. 43-38856

PUBLISHED BY AUTHORITY
OF
THE CHIEF SIGNAL OFFICER
ORDER NO. 17133-PHILA-42

SAFETY NOTICE

TAKE CARE NOT TO TOUCH THE B+ TERMINAL ON CONNECTION STRIP 36 AFTER CONNECTIONS HAVE BEEN MADE TO THE A–B– TERMINAL AND TO THE B+ TERMINAL. MAKE THE CONNECTION TO THE B+ TERMINAL BEFORE MAKING THE ONE TO THE A–B– TERMINAL. TURN THE "OFF-CRYSTAL-OPERATE-CHECK" CONTROL TO "OFF," OR WITHDRAW THE PLUG FROM THE "PHONES" JACK WHILE ALL CONNECTIONS TO CONNECTION STRIP 36 ARE BEING MADE. DON'T SHORT-CIRCUIT THE TERMINALS ON CONNECTION STRIP 36 WHILE MAKING CONNECTIONS TO THEM.

WARNING: WHILE THIS INSTRUMENT IS BEING USED TO CALIBRATE A TRANSMITTER, NEVER MAKE A DIRECT CONNECTION BETWEEN THE TRANSMITTER AND THE FREQUENCY METER.

DESTRUCTION OF ABANDONED MATERIEL IN THE COMBAT ZONE

In case it should become necessary to prevent the capture of this equipment, and when ordered to do so, **DESTROY IT SO THAT NO PART OF IT CAN BE SALVAGED, RECOGNIZED, OR USED BY THE ENEMY, BURN ALL PAPERS AND BOOKS.**

By:

1. Explosives, when provided.
2. Hammers, axes, sledges, or whatever heavy objects are readily available.
3. Burning with gasoline, oil paper, or wood.
4. Grenades and shots from available arms.

PROCEDURE:

1. Obliterate all identifying marks. Destroy nameplates and circuit labels.
2. Demolish all panels, castings, switch- and instrument-boards.
3. Destroy all controls, switches, relays, connecting means and meters.
4. Rip out all wiring in electrical equipment. Smash gas and oil lines and water cooling systems in gas-engine generators, etc.
5. Smash every electrical or mechanical part whether rotating, moving or fixed.
6. Break up all operating instruments such as keys, phones, microphones, etc.
7. Destroy all classes of carrying cases, straps, containers, etc.

DISPOSAL:

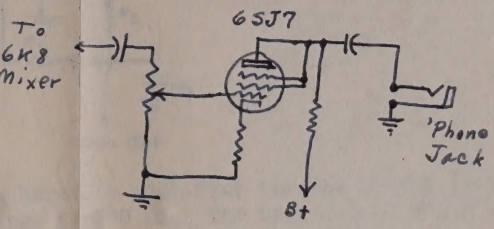
8. Where possible, and time permits, bury all debris or dispose of it in streams or other bodies of water.

Adding Tone Modulation

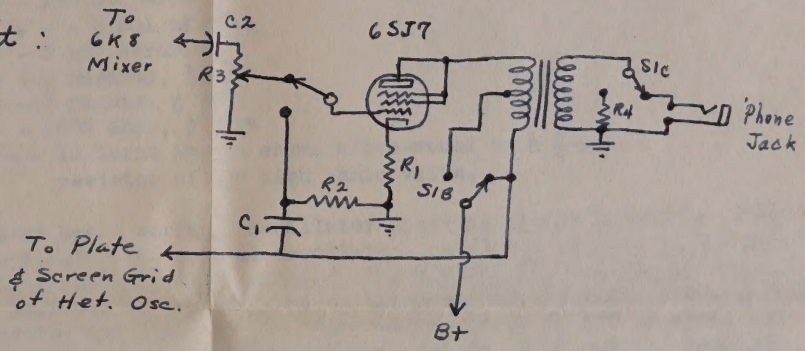
From QST May 1948 P. 68

BC-221-M

Original Circuit :

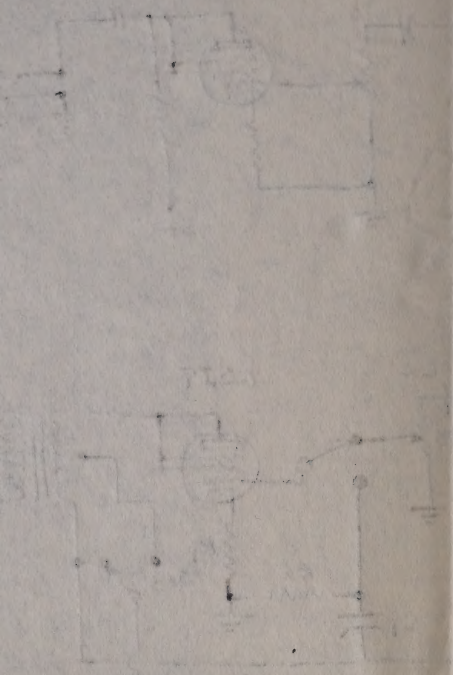


Modified Circuit :



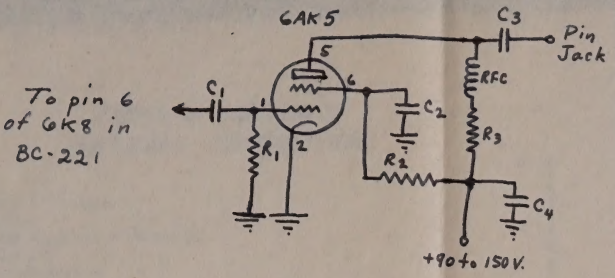
C_1 - 0.001 μf mica
C_2* - 0.02 μf paper
R_1* - 300 ohms
R_2 - 0.22 megohms, 1/2 watt
R_3* - 0.5 megohm potentiometer
R_4 - 6200 ohms, 1/2 watt
S_1 - 3 pole double-throw rotary switch
T - Push-pull output to 500 or 600 ohm line transformer
* - These components are included in the original circuit.

Percentage modulation and modulating frequency may be varied somewhat by the value of R4. 6200 ohms produces about 50% at about 800 cps.



USING THE BC-221 FREQUENCY METER AT V.H.F.

Jan. 1950 QST P. 46



Schematic diagram of a harmonic amplifier for the BC-221 frequency meter to extend its range to 300 Mc. The unit can be built on a small bracket and attached to the side of the chassis.

C1 - - 100 uuf mica
C2, C4 - - 0.001 uf mica
C3 - - 5 uuf ceramic
R1 - - 3 megohms, ½ watt
R2 - - ½ megohm, ½ watt
R3 - - 1000 ohms, ½ watt
RFC - - 15 turns No. 22 enam. close-wound on a ½-watt resistor of any high ohmic value.

The BC-221 frequency meter has a variable oscillator covering either 125-250 or 2000-4000 kc., plus a low-drift 1000-kc. crystal oscillator. Although the accuracy, dial, and stability are excellent for its original uses, its utility for frequencies above 30 Mc. is considerably improved by the addition of the harmonic amplifier shown above. The harmonics of the crystal are then audible every megacycle up to 300 or more, and by switching to "xtal check" and tuning the oscillator in the usual manner, sum-and-difference frequencies are generated. For instance, with the variable oscillator set at 200 kc., which may be accurately done by beating with the crystal, notes may be found every 200 kc. from 144 to 148 Mc., while when switching to "xtal only" only the megacycle markers remain. Similarly, when the variable oscillator is tuned to 2500 or 3500 kc., beats are evident every 500 kc. If a frequency at 144.101 Mc. were to be measured, the signal could be brought to zero beat with the variable oscillator at, say, 3101 kc. The tuning rate will be the same as it is on the fundamental frequency, but the percentage accuracy is limited mostly by the stability of the crystal. A vernier adjustment to set the crystal to zero beat with WWV would be handy. No impairment of the normal functions of the meter was noticed after the amplifier was installed.

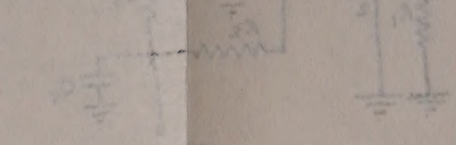


TABLE OF CONTENTS

SECTION I. DESCRIPTION

Paragraph		*Page*
1.	General	3
2.	Frequency Coverage	3
3.	Components	3
4.	Additional Equipment Required	6
5.	Total Weight	6
6.	Power Consumption	6

SECTION II. PREPARATION FOR USE

7.	Initial Procedure	7
8.	Batteries	7
9.	Antenna	9
10.	Headset	9
11.	Final Preparation for Use	9

SECTION III. OPERATION

12.	General	10
13.	Approximate Frequency Measurement	11
14.	Calibration Book MC-177-AA	12
15.	Reading the Main Tuning Dial	14
16.	To Measure the Frequency of a Nearby Transmitter	16
17.	To Tune a Transmitter to a Desired Frequency	16
18.	To Measure the Frequency to which a Transmitter is Tuned	17
19.	To Tune a Receiver to a Desired Frequency	17
20.	To Use the Crystal Frequency Directly	18
21	To Measure the Frequency of a Signal of Remote Origin	18
22.	Interpolation (to determine the dial reading when the frequency is given)	18
23.	Interpolation (to determine the frequency when the dial reading is given)	19

SECTION IV. MAINTENANCE

24.	Circuit Troubles, Simple Tests	20

SECTION V. SUPPLEMENTARY DATA

Table of Replaceable Parts	23
Suppliers for Frequency Meter BC-221-A	31

LIST OF ILLUSTRATIONS

Figure		*Page*
1.	Frequency Meter Set SCR-211-AA, Wooden Case, Showing Frequency Meter BC-221-AA and Bag	2
2.	Frequency Meter Set SCR-211-AA, Aluminum Case, Showing Frequency Meter BC-221-AA and Bag BG-81-N	4
3.	Frequency Meter BC-221-AA, Aluminum Case, Wiring of Battery Cells	7
4.	Frequency Meter BC-221-AA, Wooden Case, Wiring of Battery Cells	8
5.	Frequency Meter BC-221-AA, Schematic Diagram	11
6.	Frequency Meter BC-221-AA, Front View of Panel	14
7.	Frequency Meter BC-221-AA, Main Tuning Dial	15
8.	Frequency Meter BC-221-AA, Front Left Oblique, Viewed with Chassis Removed; Also Showing Spare Tubes in Clamps	20
9.	Frequency Meter BC-221-AA, Chassis, Rear Left Oblique View, Tuning Capacitor Shield in Place	21

Figure 1—Frequency Meter Set SCR-211-AA, Wooden Case, Showing Frequency Meter BC-221-AA and Bag

PRELIMINARY INSTRUCTIONS FOR FREQUENCY METER SET SCR-211-AA

SECTION I

DESCRIPTION

1. GENERAL

Frequency Meter Set SCR-211-AA is a portable, self-contained, instrument for the accurate determination of frequencies within the range of 125 to 20,000 kilocycles. It may be used to measure the frequency to which a transmitter or receiver is tuned, or to tune a transmitter or receiver to a given frequency. The principal component of the set is Frequency Meter BC-221-AA, which is a heterodyne frequency meter. This meter incorporates a variable frequency oscillator and a crystal controlled oscillator against which the frequency of the heterodyne oscillator may be calibrated at a number of points in each band.

2. FREQUENCY COVERAGE

Frequency Meter BC-221-AA is calibrated in two ranges, 125 to 250 kilocycles and 2,000 to 4,000 kilocycles. By the use of the 2nd, 4th and 8th harmonics of the low frequency range, any frequency between 250 and 2,000 kilocycles can be obtained, and by the use of the 2nd, 4th and 5th harmonics of the high frequency range, any frequency between 4,000 and 20,000 kilocycles can be obtained. The crystal oscillator has a frequency of 1,000 kilocycles.

3. COMPONENTS

Frequency Meter BC-221-AA is contained in one of two cases, a black wrinkle finished aluminum case as shown in Figure 1, or an olive drab wooden case as shown in Figure 2. Contained in the case are a Calibration Book MC-177-AA with typed dial readings corresponding to frequencies, two sets of tubes, one set in use and the other spare, one Crystal Unit DC-9-(*), one Bristo wrench and a compartment for batteries.

Bag BG-81-N and Strap ST-19-A are used for carrying the aluminum cased meter. A separate pocket is provided in the top of Bag BG-81-N for headphones. A compartment in the wooden cased meter is provided for carrying headphones; Strap ST-19-A is used for carrying the entire equipment.

* The asterisk within parentheses denotes the applicable issue letter.

FIGURE 2—FREQUENCY METER SET SCR-211-AA, ALUMINUM CASE, SHOWING FREQUENCY METER BC-221-AA AND BAG BG-81-N

3. LIST OF COMPONENTS OF ALUMINUM CASED FREQUENCY METER SET SCR-211-AA

No.	Name	Weight (pounds)	Height (inches)	Depth (inches)	Width (inches)
1	Bag BG-81-N . . .	2.2	16	9¼	10
1	Calibration Book MC-177-AA .	0.5			
1	Crystal Unit DC-9-(*)	0.12			
1	Frequency Meter BC-221-AA . .	16.9	13 11/16	9¼	10
2	Instructions, Preliminary, for Frequency Meter Set SCR-211-AA	0.4			
1	Strap ST-19-A . .	0.7			
4	Tubes VT-116 (two installed, two spare) . . .	0.25			

LIST OF COMPONENTS OF ALUMINUM CASED FREQUENCY METER SET SCR-211-AA—Continued

No.	Name	Weight (pounds)	Height (inches)	Depth (inches)	Width (inches)
2	Tubes VT-167 (one installed, one spare) ...	0.12			
1	Wrench for Bristo #8 Set Screw .	0.01			
		21.20			

LIST OF COMPONENTS OF WOODEN CASED FREQUENCY METER SET SCR-211-AA

No.	Name	Weight (pounds)	Height (inches)	Depth (inches)	Width (inches)
1	Calibration Book MC-177-AA .	0.5			
1	Crystal Unit DC-9-(*)	0.12			
1	Frequency Meter BC-221-AA ...	19.5	15	10	10¾
2	Instructions, Preliminary, for Frequency Meter Set SCR-211-AA	0.4			
1	Strap ST-19-A ..	0.7			
4	Tubes VT-116 (two installed, two spare) ...	0.25			
2	Tubes VT-167 (one installed, one spare) ...	0.12			
1	Wrench for Bristo #8 set screw .	0.01			
		21.6			

4. ADDITIONAL EQUIPMENT REQUIRED

The following equipment is also required to complete each Frequency Meter Set SCR-211-AA:

	Weight (pounds)
4 Batteries BA-23	7.8
6 Batteries BA-2	6.0
1 †Headset HS-30-(*) with Cord CD-605	0.4
	14.2

5. TOTAL WEIGHT

Total weight of Frequency Meter Set SCR-211-AA in aluminum case is 35.40 pounds and in wooden case is 35.80 pounds.

6. POWER CONSUMPTION

All power required for the operation of this equipment is supplied by batteries indicated in Paragraph 4. The current drains are approximately as follows:

Filaments: 6 volts (normal), 5.4 volts (min.): 0.85 amperes.

Plates, etc.: 135 volts (normal), 122 volts (min.):
Operation Switch at CHECK: 14 Milliamperes.
Operation Switch at OPERATE: 18 Milliamperes.
Operation Switch at CRYSTAL: 12 Milliamperes.

† If this cannot be obtained, Headset P-18 or P-20 shall be substituted.

SECTION II

PREPARATION FOR USE

7. INITIAL PROCEDURE

Unpack Frequency Meter Set SCR-211-AA with care and inspect it for possible damage during shipment. Check all components against the list in Paragraph 3, to see that both the quantities and types are as called for in the list.

8. BATTERIES

Open the battery compartment in the lower rear section of the cabinet. Place four Batteries BA-23 in the right-hand portion and six Batteries BA-2 next to the terminal panel.

a Connect the six Batteries BA-2 as shown in Figure 3, for the aluminum cased meter, and as shown in Figure 4 for the wooden cased meter. Splice the connecting wire and insulate the splices with tape or spaghetti. Then place the six Batteries BA-2 in the battery compartment in two tiers, the three batteries in the lower tier with their terminals up, and those in the upper tier with their terminals down. Connect the batteries to the terminal panel after installation in the battery compartment.

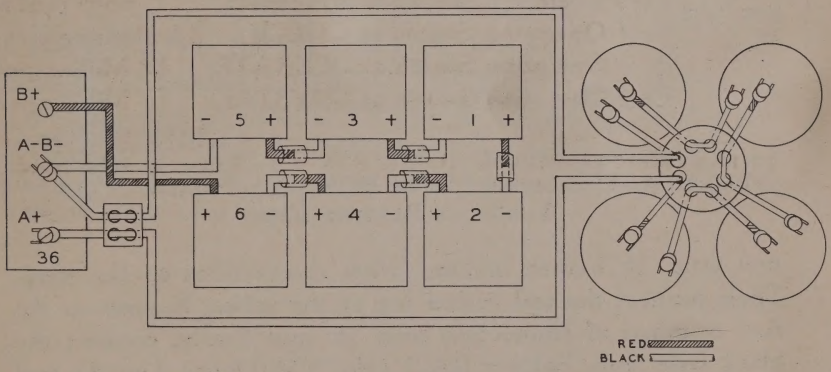


FIGURE 3—FREQUENCY METER BC-221-AA, ALUMINUM CASE, WIRING OF BATTERY CELLS

b To install the Batteries BA-23, place the four batteries in the compartments with their terminals toward the rear of the cabinet, and oriented, as shown in Figures 3 or 4 so that the

wiring harness will fit correctly. Push the batteries well forward in the cabinet. For aluminum cased meter connect the wiring harness as shown in Figure 3, making sure that the red coded lugs on the harness are connected to the positive (center) terminals of the batteries and to the A+ terminal on the connection strip 36. The Batteries BA-23 when connected in the wooden case model meter and installed have a bakelite terminal board placed over the binding posts as shown in Figure 4. After installing the battery terminal nuts and securing the positive and negative harness leads install the 3/8" wood spacer, and secure with bolt provided, to prevent short circuiting the battery. While connecting Batteries BA-2 and Batteries BA-23, be sure that loose leads do not short-circuit them. Make the connection from Battery BA-2 (No. 6 in Figure 3 or 4) to the B+ terminal on the connec-

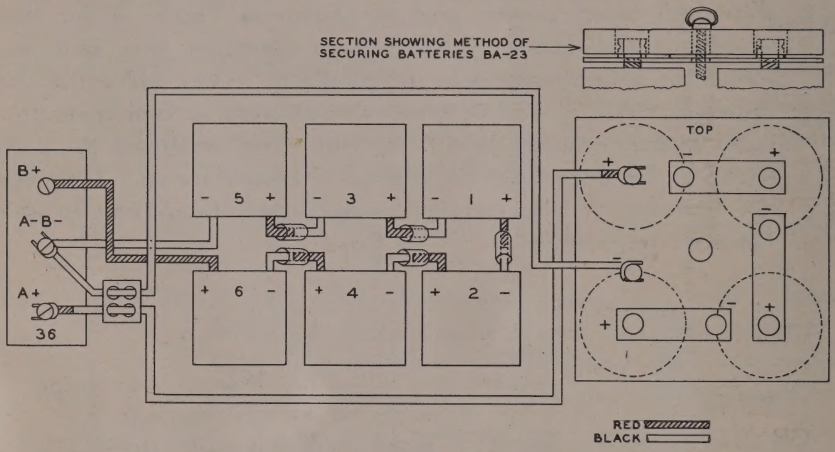


FIGURE 4—FREQUENCY METER BC-221-AA, WOODEN CASE, WIRING OF BATTERY CELLS

tion strip 36 before making other connections to the strip. Then connect the red coded lug of the wiring harness to the A+ terminal of connection strip 36, and finally, connect the black wire from Battery BA-2 (No. 5 in Figure 3 or 4) and the non-coded lug of the wiring harness to connection strip 36. CAUTION: Do not touch the B+ terminal on connection strip 36 after connections have been made at the A–B– terminal and to the A+ terminal. Operation switch should be OFF, or phone plug out of the phones from jack 31-1, or 31-2, while all connections to connection strip 36 are being

made. Take care not to short-circuit the terminals on connection strip 36 while making these connections.

After installation of the batteries, check the voltages at the connection strip 36. There should be 6 volts between A–B– and A+, and 135 volts between A–B– and B+ terminals.

9. ANTENNA

The antenna binding post 33 is located on the front panel Figure 5. A short piece of stiff, bare wire or flexible insulated wire about 2 feet long is required to couple Frequency Meter BC-221-AA to the transmitter or receiver under test. Connect this wire to the antenna post of Frequency Meter BC-221-AA in such a way that it runs approximately parallel to the antenna or antenna lead of the transmitter or receiver under test.

CAUTION: Do not actually connect Frequency Meter BC-221-AA to any part of the transmitter or receiver under test. To do so may seriously damage or ruin the meter.

10. HEADSET

A Headset HS-30-(*) used with Cord CD-605 is required to complete the installation.

11. FINAL PREPARATION FOR USE

Plug Cord CD-605 of Headset HS-30-(*) into one of the jacks marked PHONES. Turn the switch marked OFF-CRYSTAL-OPERATE-CHECK on the front panel to OPERATE and allow the meter to warm up for 20 minutes. The equipment is then ready for use.

SECTION III
OPERATION

12. GENERAL

a Measuring a frequency consists of adjusting the main dial of Frequency Meter BC-221-AA until the frequency of the beat note heard in the headset is zero cycles per second or "zero beat."

Rotating the main dial varies the frequency of the heterodyne oscillator, and when zero beat is obtained, it indicates either that the frequency of the heterodyne oscillator is of the same frequency as the frequency of the signal being measured, or that some harmonic of the heterodyne oscillator is of the same frequency as the signal being measured.

In order to know which of these conditions exists, it is necessary to know approximately the frequency of the signal being measured before measurement is made. This is very important, because in certain cases a condition of zero beat will be obtained at many different settings of the main dial and for each dial setting four frequencies are given in Calibration Book MC-177-AA. However, when the approximate frequency is known, reference to Calibration Book MC-177-AA will determine the approximate dial setting, and then the exact frequency may readily be found by varying the dial setting slightly from the approximate setting until zero beat is obtained. Several methods of finding the approximate frequency are given in Paragraph 13.

b When it is desired to adjust the frequency of a transmitter to a given value, the main tuning dial of Frequency Meter BC-221-AA is set to the corresponding setting, as determined from Calibration Book MC-177-AA, and the transmitter frequency is then varied until zero beat is obtained. As noted in the preceding paragraph, be careful to obtain the correct zero beat.

c Frequency measurements will be accurate only if the heterodyne oscillator is checked frequently against the crystal controlled oscillator in the frequency meter.

13. APPROXIMATE FREQUENCY MEASUREMENT

a **Successive zero beats.**

In order to insure against using an incorrect zero beat, find the approximate frequency by using the frequency meter as follows. Determine from the second column in the Calibration

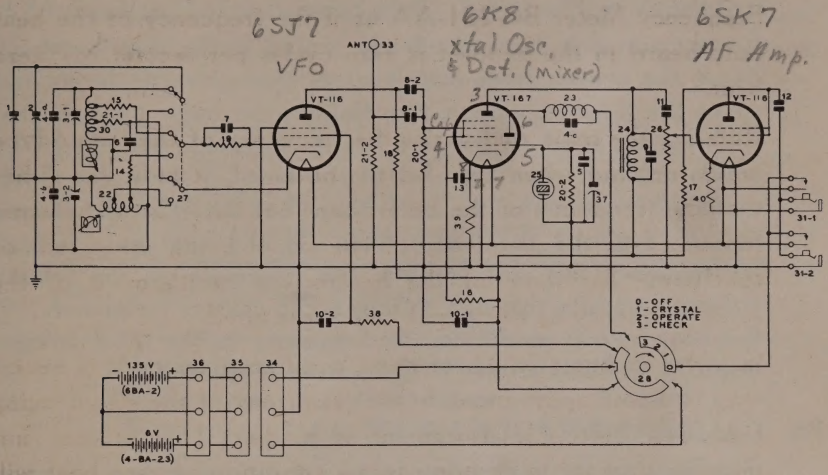


FIGURE 5—FREQUENCY METER BC-221-AA, SCHEMATIC DIAGRAM

Book MC-177-AA the exact frequencies corresponding to two successive dial settings in either band in which zero beat is obtained. Call the lower of these two frequencies F_1 and the higher F_2. Then F_0 the unknown frequency, can be found by the formula:

$$F_0 = \frac{F_2 \times F_1}{F_2 - F_1}$$

As an example, suppose zero beats are obtained in the low frequency band at the dial settings, corresponding to 220.0 Kc., 192.5 Kc., 171.1 Kc., 154.0 Kc., and 140.0 Kc. Substitute any two successive frequencies for F_2 and F_1; for instance let $F_2 = 171.1$ and $F_1 = 154.0$. Then:

$$F_0 = \frac{171.1 \times 154.0}{171.1 - 154.0} = 1540 \text{ KC. (Approximately)}$$

Having made this calculation, proceed as in Paragraph 16 to determine the exact value of F_0, the unknown frequency.

b **Variation of beat note.**

The procedure outlined in Paragraph 13a for finding approximate frequency fails only when one zero frequency can be found in the band. If this occurs, in the high frequency band, switch to the low frequency band and several zero beat frequencies will be found. Then proceed as in Paragraph 13 *a*.

If only one zero beat frequency occurs in the low frequency band, the correct frequency is either that given in the second or in the third column in the Calibration book opposite the dial reading at which the zero beat is obtained. To determine which column, reset the dial to the reading given for a frequency 10 Kc. higher or lower than that shown in the second column opposite the dial setting. If the beat note is high in frequency but still **audible,** the frequency in the second column opposite this dial setting is the correct frequency. If the beat note is **inaudible,** the frequency in the third column opposite the dial setting is the correct frequency.

14. CALIBRATION BOOK MC-177-AA

The body of the calibration table is arranged in five columns. The first half of the book contains the calibration for the low frequency band. In the first column are the dial settings, in the second, the fundamental frequencies of the heterodyne oscillator corresponding to the dial settings, and in the third, fourth and fifth columns the corresponding 2nd harmonic, 4th harmonic, and 8th harmonic frequencies respectively, which are obtained at the same dial settings.

In the second half of the book, which contains the calibration for the high frequency band, the fifth column, where used, contains 5th rather than 8th harmonic frequencies. As an example, if the FREQ BAND switch is at low and the scale reads about 0340, the fundamental frequency of the heterodyne oscillator is 130.0 Kc. (The exact dial setting for a given frequency varies between individual meters.) At the same dial setting, the heterodyne oscillator is also producing signals of 260.0, 520.0 and 1040.0 Kc., and a beat note will be heard in the headset if the frequency under test is close to any one of these harmonics, or any other integral multiple of 130.0 Kc.

Certain frequencies in the table called crystal "check points" are printed in red. When the heterodyne oscillator is set to

one of these frequencies, and the operation switch is turned to CHECK, a beat note will be heard in the headphones between some harmonic of the heterodyne oscillator and some harmonic of the crystal oscillator. When the CORRECTOR knob is turned to give zero beat, with the dial set according to the calibration book at one of the crystal check points, the calibration of the meter will be accurate for all settings near the crystal check point. At the bottom of each page is given the frequency of the nearest such check point.

Use the calibration book with frequency meter bearing the same serial number. Make sure these numbers are identical.

In order that there may be no confusion as to the actual crystal check points the beat points encountered at the various **lowest harmonic combinations** of the two oscillator frequencies are given in the following tabulations:

Heterodyne Fundamental Frequency	Lowest Heterodyne Harmonic	Lowest Crystal Harmonic
125.00	8	1
133.33	15	2
142.86	7	1
153.85	13	2
166.67	6	1
181.82	11	2
200.00	5	1
214.29	14	3
222.22	9	2
230.77	13	3
250.00	4	1
2000.0	1	2
2166.7	6	13
2250.0	4	9
2333.3	3	7
2500.0	2	5
2666.7	3	8
2750.0	4	11
3000.0	1	3
3250.0	4	13
3333.3	3	10

Heterodyne Fundamental Frequency	Lowest Heterodyne Harmonic	Lowest Crystal Harmonic
3500.0	2	7
3666.7	3	11
3750.0	4	15
4000.0	1	4

15. READING THE MAIN TUNING DIAL

The main tuning dial consists of three parts, a drum marked DIAL HUNDREDS, a disc marked DIAL UNITS, and a vernier scale. Each division of the DIAL HUNDREDS drum corresponds to one full rotation of the DIAL UNITS disc which has 100 divisions. The vernier scale, which is immediately above the DIAL UNITS disc, reads in tenths of one division on the DIAL UNITS disc.

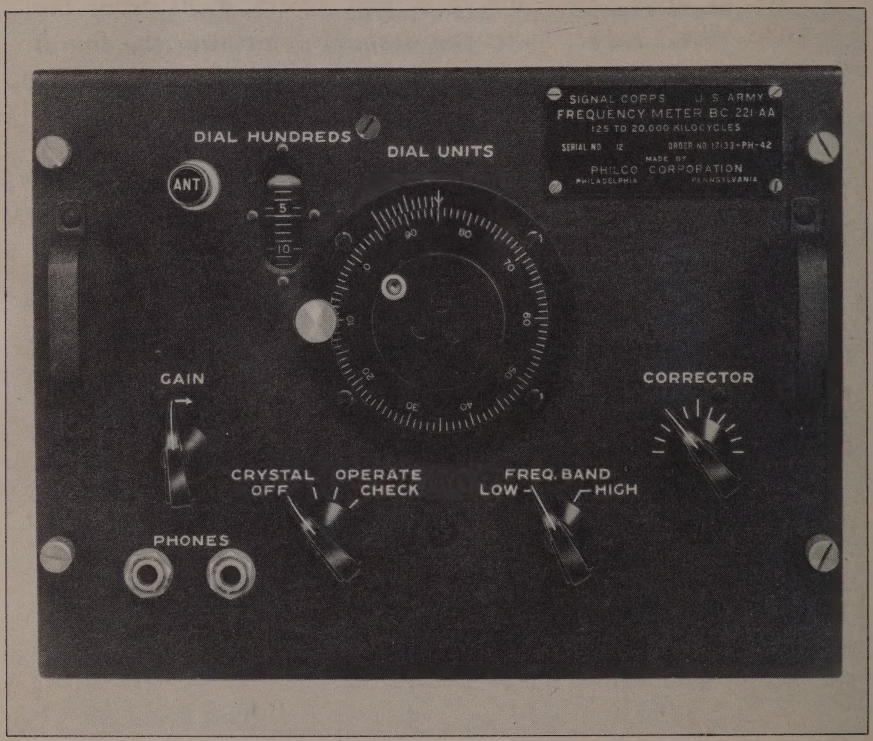


FIGURE 6—FREQUENCY METER BC-221-AA, FRONT VIEW OF PANEL

It will be noted that the vernier scale has ten divisions which occupy the same distance that is covered by nine divisions of the DIAL UNITS disc. When the DIAL UNITS disc is set so that the index arrow coincides exactly with a line upon the dial, it will be found that the last mark upon the vernier scale also coincides with a line upon the DIAL UNITS disc. Should the DIAL UNITS disc be set so that the index arrow falls between two successive marks on the dial, there will be found some line on the vernier scale which coincides, or very nearly coincides, with a line upon the DIAL UNITS disc. The number of vernier divisions between the index arrow and the "coinciding" mark denotes tenths of a dial division. This reading should be added to the last unit which may be read from the DIAL UNITS disc. To read the main tuning dial, read the first two digits from the DIAL HUNDREDS drum; read the third and fourth digits from the DIAL UNITS disc; insert the decimal point after the fourth digit; read the first digit after the decimal point from the vernier. In Figure No. 7 the dial reading is 3856.7.

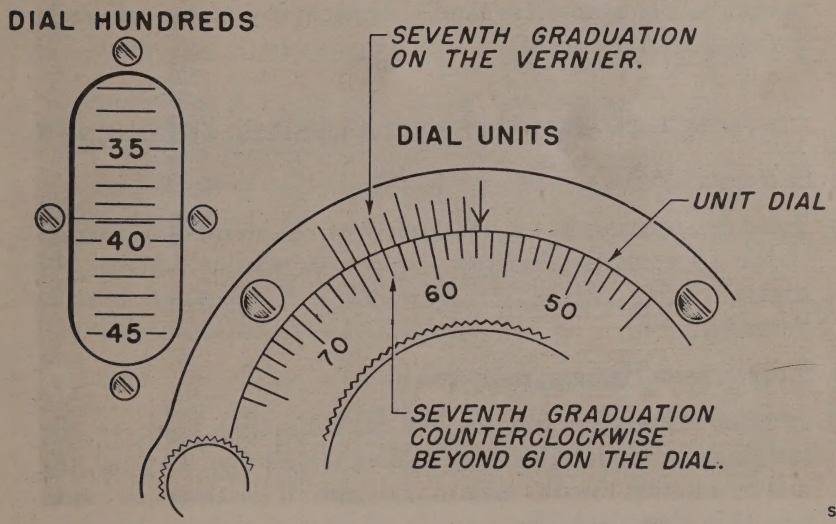


FIGURE 7—FREQUENCY METER BC-221-AA, MAIN TUNING DIAL

16. TO MEASURE THE FREQUENCY OF A NEARBY TRANSMITTER

a Turn the operation switch knob to CHECK and plug Cord CD-605 of Headset HS-30-(*) into one of the jacks marked PHONES.

b Allow frequency meter to heat up for 20 minutes.

c If the approximate frequency is not known, determine it by proceeding as in Paragraph 13.

d Look up the approximate frequency in the calibration book and set the main tuning dial to the nearest crystal check point.

e Adjust the CORRECTOR knob until zero beat is heard in the headset and do not disturb this setting during the remainder of the measurement.

f Turn the operation switch knob to OPERATE.

g Place frequency meter with its antenna near and parallel to **but not touching** the transmitter antenna or antenna lead.

h Set the main tuning dial at the approximate frequency and adjust until zero beat is obtained.

i Read the main tuning dial and look up the corresponding frequency in the calibration book. If necessary interpolate as in Paragraph 23.

17. TO TUNE A TRANSMITTER TO A DESIRED FREQUENCY

a Proceed as in Paragraph 16 *a* and *b*.

b Tune the transmitter approximately to the desired frequency. If the approximate frequency is not known in terms of the tuning of the transmitter, determine it by proceeding as in Paragraph 13.

c Proceed as in Paragraph 16 *d* to *g*.

d Look up the desired frequency in the calibration book, set the main tuning dial to the corresponding dial setting, and lock the dial by rotating the dial lock to the right. If necessary, interpolate as in Paragraph 22.

e Vary the transmitter tuning until zero beat is obtained.

18. TO MEASURE THE FREQUENCY TO WHICH A RECEIVER IS TUNED

a Proceed as in Paragraph 16 *a*, *b*, and *d* to *f*.

b Place the Frequency Meter BC-221-AA with its antenna near and parallel to, **but not touching,** the receiver antenna or antenna lead.

c If the receiver has a local c-w oscillator, turn it on. Then turn the main tuning dial of the frequency meter to a position near that for the approximate frequency, at which the maximum audio output is obtained from the receiver under test. Vary the frequency of the c-w oscillator in the receiver in such a way as to keep the audio output at some convenient frequency.

d Read the main tuning dial of the frequency meter and look up the corresponding frequency in the calibration book. If necessary, interpolate as in Paragraph 22.

e If the receiver has no local c-w oscillator, it is necessary to couple loosely to the receiver antenna an external oscillator, which is then used like the receiver heterodyne oscillator in Paragraph 18 *c*.

19. TO TUNE A RECEIVER TO A DESIRED FREQUENCY

a Proceed as in Paragraph 16 *a*, *b*, and *d* to *f*.

b Place the frequency meter with its antenna near and parallel to, **but not touching,** the receiver antenna or antenna lead.

c Look up the desired frequency in the calibration book, set the main tuning dial to the corresponding dial setting, and lock the dial by rotating the dial lock to the right. If necessary, interpolate as in Paragraph 22.

d If the receiver has a local c-w oscillator, tune the receiver for maximum audio output, varying the local c-w oscillator frequency in such a way as to keep the audio output at some convenient frequency.

e If the receiver has no local c-w oscillator, use an external oscillator as in Paragraph 18 *e*.

20. TO USE THE CRYSTAL FREQUENCY DIRECTLY

To use the signal emitted by the crystal oscillator in the frequency meter directly, set the operation switch to CRYSTAL, in which case a one thousand kilocycle signal and its harmonics are radiated by the frequency meter antenna.

21. TO MEASURE THE FREQUENCY OF A SIGNAL OF REMOTE ORIGIN

a Tune the signal with a receiver.

b If the receiver has a local c-w oscillator, turn it off.

c Proceed as in Paragraph 16 *a* to *f*.

d Place the frequency meter with its antenna near and parallel to, but not touching the receiver antenna or antenna lead.

e Turn the main tuning dial of the frequency meter to a position near that for the approximate frequency; then vary it a little from this position until zero beat is obtained in the receiver.

f Read the main tuning dial and look up the corresponding frequency in the calibration book. If necessary, interpolate as in Paragraph 23.

22. INTERPOLATION (To determine the dial reading when the frequency is given)

Dial readings corresponding to frequencies between successive values given in the calibration book may be found as follows:

a Locate a dial reading D_1 corresponding to Frequency F_1 below the desired frequency F_0.

b From the bottom of the proper page in the calibration book obtain divisions per kilocycle. If the desired frequency is found on pages 3 through 27, second column, the divisions per kilocycle may be used directly. If the desired frequency is found in the third, fourth or fifth columns of pages 3 through 27, divide the average dial divisions per kilocycle by 2, 4, or 8, respectively. If the desired frequency is found in the calibration book, pages 32 through 71, in the second column, the divisions per kilocycle may be used directly. If the frequency is found in the third, fourth, or fifth columns on pages 32

through 71, the divisions per kilocycle should be divided by 2, 4 or 8, respectively.

c The dial reading D_0 which corresponds to frequency F_0 can then be found by the formula:

$$D_0 = D_1 + (F_0 - F_1) \times \text{Divisions Per Kilocycle.}$$

Example: If the desired frequency F_0 is 1004.3 Kc. then F_1 = 1004.0 Kc. (See page 4 in the calibration book.) The corresponding dial reading might be D_1 = 0222.9. The exact reading will vary among individual books.

Then divisions per kilocycle will be:

$$\frac{39.7}{8} = 4.96$$

and $D_0 = 0222.9 + (1004.3 - 1004.0) \times 4.96 = 0224.39.$

Set the dial to the nearest tenth of a division, which in this case is 0224.4.

23. INTERPOLATION (To determine the frequency when the dial reading is given)

Frequencies corresponding to dial readings between successive readings given in the calibration book may be found as follows:

a Find the divisions per kilocycle as in Paragraph 22 *a* and *b*.

b The frequency F_0 which corresponds to dial reading D_0 can then be found by the formula:

$$F_0 = F_1 + \frac{(D_0 - D_1)}{\text{Divisions Per Kilocycle}}$$

Example: If the known dial reading, D_0 is 2482.5 and the frequency is known to be approximately 6000 kilocycles, then reference to one particular calibration book shows D_1 = 2481.8 and the corresponding frequency is F_1 = 5894 Kc.

Divisions per kilocycle are:

$$\frac{2.2}{2} = 1.1$$

and

$$F_0 = 5894 + \frac{2482.5 - 2481.8}{1.1} = 5894.63$$

Read the frequency to the nearest tenth of a kilocycle, in this case, 5894.6 Kc.

SECTION IV

MAINTENANCE

24. CIRCUIT TROUBLES, SIMPLE TESTS

Faulty operation may be due to the failure of either the crystal circuit, the oscillator circuit, or the amplifier circuit; the lack of resultant beats causing no sound in the headset. (As a precaution, make sure that the headset plug is making good contact.) Use the following tests to isolate trouble:

a To determine whether the crystal circuit has failed, turn the operating knob to CRYSTAL. Under normal conditions, the set is radiating the crystal frequency at this position and an oscillating receiver, tuned to 1,000 kilocycles, should readily detect the radiation.

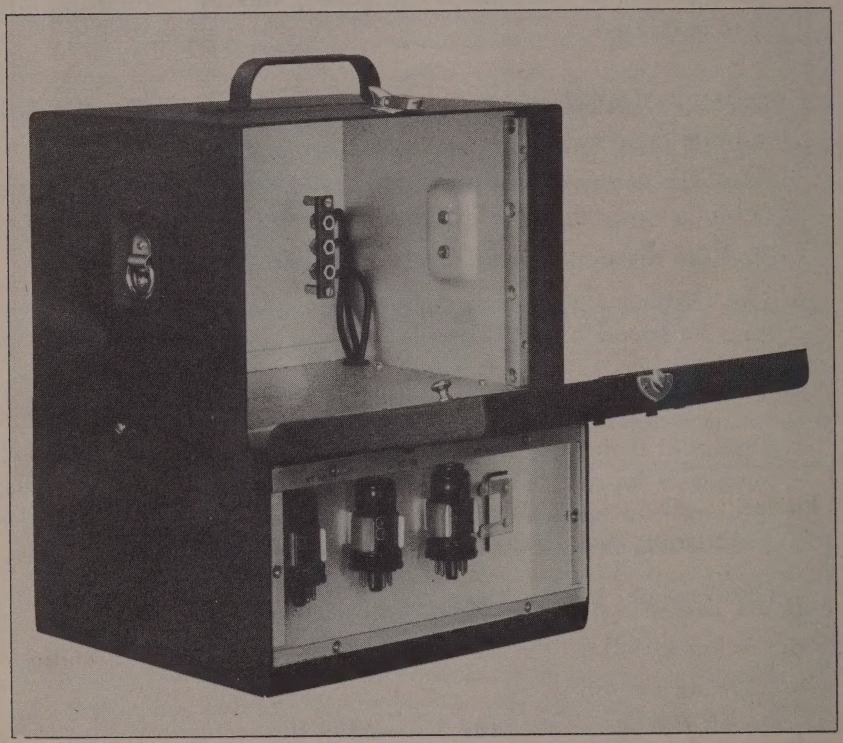


FIGURE 8—FREQUENCY METER BC-221-AA, FRONT LEFT OBLIQUE, VIEWED WITH CHASSIS REMOVED; ALSO SHOWING SPARE TUBES IN CLAMPS

b To determine whether the oscillator circuit has failed, turn the operating knob to OPERATE and repeat the above test. An oscillator frequency should ordinarily be emitted and its presence can be detected by an oscillating receiver.

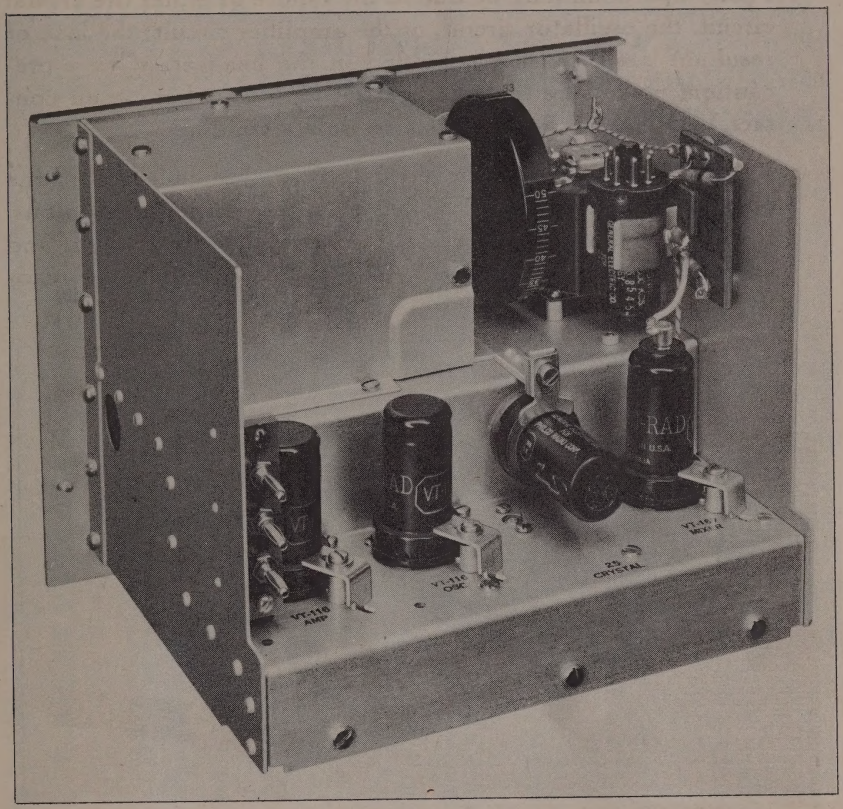


FIGURE 9—FREQUENCY METER BC-221-AA, CHASSIS, REAR LEFT OBLIQUE VIEW, TUNING CAPACITOR SHIELD IN PLACE

c If the preceding tests *a* and *b* indicate that these circuits are operating satisfactorily, the trouble probably lies in the audio amplifying circuit.

In the defective circuit, remove and replace the tube or crystal once or twice to insure good contact in the socket. If there is no improvement replace the doubtful item with its spare.

NOTE: NEVER MAKE REPAIRS OTHER THAN THOSE OF A VERY MINOR NATURE SUCH AS REPLACING TUBES AND CRYSTAL. ONLY TRAINED PERSONNEL AT SIGNAL CORPS REPAIR SHOPS AND SIGNAL CORPS RADIO STATIONS AT AIR DEPOTS, ADEQUATELY EQUIPPED WITH THE PROPER TOOLS AND INSTRUMENTS ARE AUTHORIZED TO UNDERTAKE SUCH REPAIR SERVICE.

SECTION V SUPPLEMENTARY DATA

TABLE OF REPLACEABLE PARTS
FOR
FREQUENCY METER BC-221-AA

Ref. No.	Sig. C. Stock No.	Name of Part and Description	Function	Mfr.	Contractors' Drawing No.
1		Capacitor, variable, 2.2 μμf (min.), 200 μμf (max.), 15 rotor and 15 stator plates Type #358-2519	Oscillator tuning	L	358-2519
2		Capacitor, variable, 1.8 μμf (min.), 3 μμf (max.), working voltage 300, 3 plates	Corrector	C	361-1011
3–1		Capacitor, variable, 3 μμf (min.), 18 μμf (max.), ±2 μμf working voltage 300, 3 rotor and 4 stator plates	Trimmer, low frequency	C	361-1027
3–2		Capacitor, variable, 3 μμf (min.), 18 μμf (max.), ±2 μμf working voltage 300, 3 rotor and 4 stator plates	Trimmer, high frequency	C	361-1027
4–a		Capacitor, 10 μμf ±0.5 μμf, working voltage 300, ceramic, 350 x 10-6 μμf/μμf/deg. C, Neg. Temp. Coef. Type #13N350	Drift compensation, low frequency	D	305-1254
4–b		Capacitor, 10 μμf ±0.5 μμf, working voltage 300, ceramic, 200-250 x 10-6 μμf/μμf/deg. C, Neg. Temp. Coef. Muter Type #13N200 Erie Type #N220K100 Central Radio Type #811-109	Drift compensation, high frequency	D E F	306-1074

TABLE OF REPLACEABLE PARTS FOR FREQUENCY METER BC-221-AA—Continued

Ref. No.	Sig. C. Stock No.	Name of Part and Description	Function	Mfr.	Contractors' Drawing No.
4–c		Capacitor, 10 μμf ±0.5 μμf, working voltage 300, ceramic, 350-400 x 10-6 μμf/μμf/deg. C, Neg. Temp. Coef. Type #13N350	Shunt on crystal choke	D	306-1058
5		Capacitor, 6.5 μμf ±0.5 μμf working voltage 300, ceramic, zero coefficient	Across crystal		306-1084
6		Capacitor, 250 μμf ±10%, working voltage 200, molded silver mica, waxed Micamold Type #503M Electro Motive Type#0	6 Low frequency cathode tap	B A	306-1078
7		Capacitor, 15 μμf ±10%, working voltage 200, molded low loss, phenolic Type #603M	Grid coupling	A	306-1025
8–1		Capacitor, 25 μμf ±20%, working voltage 200, molded low loss, phenolic Electro Motive Type #503M Aerovox Type #1468 Micamold Type #0	Antenna coupling	A G B	306-1076
8–2		Capacitor, 25 μμf ±20%, working voltage 200, molded low loss, phenolic Electro Motive Type #503M Aerovox Type #1468 Micamold Type #0	Plate—grid coupling	A G B	306-1076
9		Capacitor, 0.002 μf ±10%, working voltage 500, molded phenolic, waxed Type #W	Detector plate r-f by-pass	B	306-1061

10–1	Capacitor, 0.1 μf +14% –6%, working voltage 200, oil filled paper Aerovox Type #43011 Electrical Utilities Type #10728	Plus B by-pass	G H	306-1012
10–2	Capacitor, 0.1 μf +14% –6%, working voltage 200, oil filled paper Aerovox Type #43011 Electrical Utilities Type #10728	Pentode screen	G H	306-1012
11	Capacitor, 0.25 μf +14% –6%, working voltage 200, oil filled paper Aerovox Type #43025 Electrical Utilities Type #10415-1	Detector-audio coupling	G H	306-1013
12	Capacitor, 2.0 μf +14% –6%, working voltage 200, oil filled paper Aerovox Type #4302 Sprague Type #P3699	Coupling audio output	G I	306-1014
13	Capacitor, 0.001 μf ±10%, working voltage 300, molded low loss phenolic, waxed Aerovox Type #1467 Micamold Type#W	Mixer screen by-pass	G B	306-1016
14	Resistor, 27 ohm ±10%, ½ watt, carbon, insulated Type #MD½	Suppressor, high frequency	J	363-1023
15	Resistor, 1500 ohm ±10%, ½ watt carbon, insulated, waxed. Part of item #30 International Resistance Type #BT½ Stackpole Type #MD½	Suppressor, low frequency	K J	363-1024
16	Resistor, 10,000 ohm ±10%, ½ watt, metallized filament, insulated Stackpole Type #MD½	Voltage dropping screen of converter	J	66-3103370

TABLE OF REPLACEABLE PARTS FOR FREQUENCY METER BC-221-AA—Continued

Ref. No.	Sig. C. Stock No.	Name of Part and Description	Function	Mfr.	Contractors' Drawing No.
17		Resistor, 15,000 ohm ±10%, ½ watt, metallized filament, insulated Stackpole Type #MD½	Audio load resistor	J	66-3153370
18		Resistor, 50,000 ohm ±10%, ½ watt, metallized filament, insulated International Resistance Type #BT½ Stackpole Type #MD½	Oscillator plate resistor	K J	66-3503370
19		Resistor, 330,000 ohm ±10%, ½ watt, carbon, insulated waxed International Resistance Type #BT½	Grid resistor oscillator tube	K	363-1022
20–1		Resistor, 1.0 megohm ±20%, ½ watt, metallized filament, insulated International Resistance Type #BT½	Grid resistor Tube VT-167	K	66-5103570
20–2		Resistor, 1.0 megohm ±20%, ½ watt, metallized filament, insulated International Resistance Type #BT½	Crystal shunt	K	66-5103570
21–1		Resistor, 5000 ohm ±10%, ½ watt, metallized filament, insulated International Resistance Type #BT½ Stackpole Type #MD½	Antenna shunt	K J	66-2503370
21–2		Resistor, 5000 ohm ±10%, ½ watt, metallized filament, insulated International Resistance Type #BT½ Stackpole Type #MD½	Oscillator cathode low frequency	K J	66-2503370

22		Coil Assy., 25.84 microhenries, universal wound, waxed Type #368-1415	Oscillator, high frequency	L	368-1415
23		Choke Assy., 735 microhenries ±10%, universal wound, waxed coil	Aperiodic plate choke	M	368-1323
24		Choke, 40 henries +20% -10% at 1.0 ma. D-C 10,000 turns of #41 special P.E. copper wire	Audio reactor plate of detector	N	362-7002
25		Crystal, 1000 KC. Bliley Type #DC-9-P General Electric Type #DC-9-AD	Crystal oscillator	O P	465-1001
26		Potentiometer, 0.5 megohm ±20%, variable	Gain control	Q	363-5000
27		Switch, 3 pole, 2 position	Switch bands		462-1016
28		Switch, 2 pole, 4 position Type #22739-H1	OFF Switch and 3 positions of operation	C	462-1004
30		Coil Assy., 7.06 millihenries, ceramic, isolantite form, bank wound, enameled wire Type #368-1416	Oscillator—low frequency	L	368-1416
31–1		Jack Assy., Single jack for Plug PL-55	Closing and opening phone and filament circuits	Q	368-1043
31–2		Jack Assy., Single jack for Plug PL-55	Closing and opening phone and filament circuits	Q	368-1043
33		Antenna Post, Spring plunger type	Antenna terminal		258-3878
34		Plug Assy., 3 banana plugs on single panel Type #115019	Power connection	T	368-1044

TABLE OF REPLACEABLE PARTS FOR FREQUENCY METER BC-221-AA—Continued

Ref. No.	Sig. C. Stock No.	Name of Part and Description	Function	Mfr.	Contractors' Drawing No.
35		Jack Assy., 3 jacks on terminal board Type #115018	Power connection	T	368-1035
36		Connection Strip, 3 jacks on connection strip Type #115020	Connecting batteries	T	368-1089
37		Capacitor, 3.1 μμf (min.), ±7%, 15.1 μμf (max.) ±7%, 4 plates	Across crystal	M	361-1033
38		Resistor, 20,000 ohm, ±10%, ½ watt, metallized filament International Resistance Type #BT½	Voltage dropping screen of oscillator	K	66-3203370
39		Resistor, 150 ohm ±10%, ½ watt, metallized filament International Resistance Type #BT½	Bias for Tube VT-167	K	66-1153370
40		Resistor, 350 ohm ±10%, ½ watt, metallized filament International Resistance Type #BT½	Bias for audio Tube VT-116	K	66-1353370
		Tube VT-116 r-f Pentode, Type 6SJ7 tube R.C.A. Type #6SK7	Variable frequency oscillator	U V	354-1010
		Tube VT-167 Triode Hexode Converter, Type 6K8 tube R.C.A. Type #6K8	Crystal oscillator and detector	U V	354-1011
		Tube VT-116 r-f Pentode, Type 6SJ7 tube R.C.A. Type #6SK7	Audio amplifier	U V	354-1010
		Knob, smooth grip bakelite	Corrector		368-1419
		Knob, smooth grip bakelite	Band switch		368-1419

Knob, smooth grip bakelite	Gain control		368-1419
Knob, smooth grip bakelite	Operation switch		368-1419
Dee Plate, brass Type #268-1195	Mounting plate, two used	L	268-1195
Dee Ring, brass	Dee ring, two used	W	268-1193
†Cable Assy.	Battery		358-3088
Cable Assy.	Chassis wiring		467-1012
Wiring Panel Assembly	Hook-up		368-1300
Antenna Panel Assembly	Hook-up		358-3136
Oscillator Assembly	Oscillator unit		368-1344
Grommet, gum rubber	Wire feed through	X	267-4060
Grommet, gum rubber Type #61	Wire feed through	Y	267-4028
Grommet, gum rubber	Wire feed through	X	267-4077
Circuit label	Circuit		257-7925
Crystal Clamp, steel	Crystal mtg.	R	268-1356
Wire	Hook-up		
Tube Clamp (3), steel	Clamp		268-1357
Tube socket (3), octal socket, micanol base	Tube mounting		267-4108
Crystal socket assembly, octal socket, micanol base Type #9865	Crystal	S	267-4107

TABLE OF REPLACEABLE PARTS FOR FREQUENCY METER BC-221-AA—Continued

Ref. No.	Sig. C. Stock No.	Name of Part and Description	Function	Mfr.	Contractors' Drawing No.
		Bushing, bakelite			257-7783
		Post, spring plunger type			258-3878
		Bushing, Isolantite			257-7782
		Washer, untreated fishpaper			257-8052
		Washer, untreated fishpaper			267-4023
		Nut		AA	2W19986FA43
		Lockwasher			4W35045FA7
		*Cable Assy.	Battery		368-1075
		*Bumper Assy., rubber	Battery bumper	Z	368-1065
		*Plug, banana type	Ground plug	T	268-1176
		*Insulator Type #135216	Battery insulator	T	267-4063

* Used only in aluminum cased Frequency Meter BC-221-AA.
† Used only in wooden cased Frequency Meter BC-221-AA.

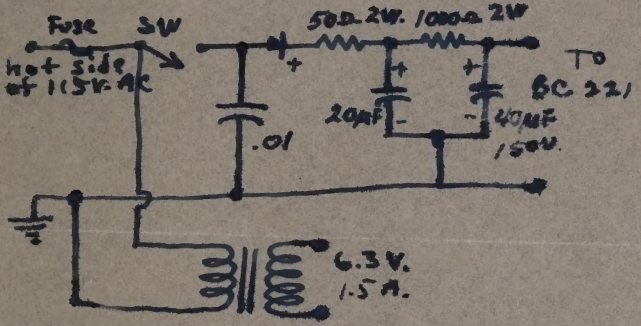
SUPPLIERS FOR FREQUENCY METER BC-221-AA

Code No.	Name	Address
A	Electro Motive Co.	Willimantic, Conn.
B	Micamold Corporation	1087 Flushing Ave., Brooklyn, N. Y.
C	Oak Manufacturing Co.	1260 Claybourn Ave., Chicago, Ill.
D	The Muter Company	1225 S. Michigan Ave., Chicago, Ill.
E	Erie Resistor Co.	Erie, Pa.
F	Central Radio Laboratory	900 E. Keefe Ave., Milwaukee, Wis.
G	Aerovox Corporation	741 Belleville Ave., New Bedford, Mass.
H	Electrical Utilities Co.	2900 S. Michigan Ave., Chicago, Ill.
I	Sprague Specialties Co.	N. Adams, Mass.
J	Stackpole Carbon Co.	St. Mary's, Pa.
K	International Resistance Co.	401 N. Broad St., Philadelphia, Pa.
L	Philco Corporation	C & Tioga Streets, Philadelphia, Pa.
M	F. W. Sickles Co.	Box 920, Springfield, Mass.
N	Jefferson Electric Co.	Bellewood, Ill.
O	Bliley Electric Co.	Union Station Bldg., Erie, Pa.
P	General Electric Co.	Schenectady, N. Y.
Q	Chicago Telephone Supply Co.	Elkhart, Ind.
R	G. K. Garrett Co.	D & Tioga Streets, Philadelphia, Pa.

SUPPLIERS FOR FREQUENCY METER BC-221-AA—Continued

Code No.	Name	Address
S	Cinch Manufacturing Co.	2335 W. Van Buren St., Chicago, Ill.
T	Ucinite Company	359 Watertown St., Newtonville, Mass.
U	RCA Manufacturing Co.	Harrison, N. J.
V	Ken-Red Company	Owensboro, Ky.
W	H. L. Judd Company	87 Chamber St., New York, N. Y.
X	Canfield Rubber Co.	Railroad Ave. & Garden St., Bridgeport, Conn.
Y	Pierce-Roberts Rubber Co.	Trenton, N. J.
Z	Scully Rubber Co.	Highlandtown Station, Baltimore, Md.
AA	Fischer Special Mfg. Co.	3701 N. Broad St., Philadelphia, Pa.

BC 221 Power Supply



Selenium rectifier, 100 ma. Federal

FWD Resistance 6000 Ω
Back " 1½ Megohms

Philco Part No. 369-1282